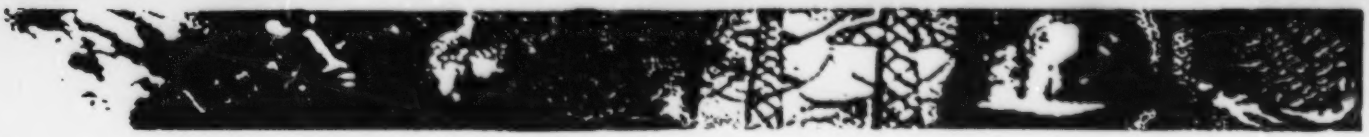

Summary Reports of ETF Workshops and Technology Focus Groups

August 1998 to February 1999

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CONTEXTUAL ASSUMPTIONS
ENERGY TECHNOLOGY FUTURES 2030

MACROECONOMIC & DEMOGRAPHIC CONTEXT ASSUMPTIONS

The ETF project is building scenarios for the energy technologies Canada could be using circa 2020 - 2050 which could de-couple GHG emissions from economic growth. This paper outlines the long-term macroeconomic and demographic assumptions that will provide a general context for the project.[1]

These assumptions will provide the ETF project with:

- general trends in demographic and economic conditions for the development of the ETF scenarios,
- greater understanding of the nature of energy service demands in the ETF time frame,
- insights into potential long-term future challenges for energy technologies.

This paper supports by a more detailed presentation of charts available through the ETF office.

Global Context

Canada's longer-term response to climate change issues will depend in part on the global population, economic and energy situation. Studies by international agencies suggest that world population could double by about 2050, and that by the same time, world economic output could increase 3 to 5 fold, and by as much as 15 fold by 2100. (See for example, World Energy Council: Energy for Tomorrow's World, and the International Institute for Applied Systems Analysis: Global Energy Prospects to 2050 and Beyond.) Much of this growth will be coming from currently developing countries.

The IEA document, 'World Energy Prospects to 2020' indicates that annual economic growth for non-OECD countries will average about 3.75% over that period, while OECD country growth will be less than 2% per annum. Thus, per capita levels of income in developing countries can be expected to surpass those of today's developed economies by or before, the middle 21st century.

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[1] Please refer to the project web site at **http://www.nrcan.gc.ca/es/etf** for the scope, objectives and early results of the ETF project.

This level of economic growth will have with it a resultant increase in the level of energy service demand and in the demand for primary energy. The amount of primary energy per unit of GDP will decline as energy intensities improve. Improved conversion efficiencies, capital stock turnover and economies of scale in the production of newer technologies could result in intensity improvements ranging from 0.8 to 1.4% per year. However, even with these improvements, primary energy demand could be expected to increase by 1.5 to 3 times current levels by 2050, and possibly double again by 2100.

Canadian Context

The assumptions that are being used in the analytical component of the federal government's response to the climate change issue are those provided in the Business as Usual case contained in "Canada's Energy Outlook: 1996-2020', prepared by Natural Resources Canada. For consistency, the ETF project is grounded in these same assumptions through to 2020.

In the Base Case, the population of Canada is seen as growing from 31 million in 2000 to 36.8 million in 2020 (0.86% per year). The number of households will increase faster than the overall population from 11.2 to 14.6 million (1.33% per year) due mainly to changes in age structure.

The Outlook estimates annual growth rate for the Canadian GDP at 2.2% from 1995 to 2010 then declining to 2.1% per year by 2020. The industrial sector is forecast to slow from an annual growth rate of 3.1% in 1995-2000 to 2.0% in 2000-2010, then declining slightly to 1.9% by 2020. The service sector is forecast to grow somewhat more rapidly from 1.7% per year in 1995-2000, to 2.3% per year by the year 2020.

The Outlook assumes, in the absence of additional policies and programs that energy end-use demands will grow to 3340 PJ by 2020, 45% above 1990 levels. The potential impact of GHG reduction initiatives already accounted for in the residential, commercial, industrial and transportation sectors could reduce those levels by almost 600 PJ in 2020.

As the timeframe for the ETF project extends beyond the 2020 period, additional projections beyond 2020 are needed.

Demographic Projections for Canada Beyond 2020

Statistics Canada (publication 91-520) provided demographic information on population size, structure and distribution to the year 2041. In addition, ETF requested special runs from Statistics Canada on the population distribution of major Census Metropolitan Areas (CMAs).

The Statistics Canada projections show that by 2041 the total size of Canada's population will grow from its current level of 32 million to between 36 and 50 million people. The main factor in defining this range is the level of annual net immigration. The lower value for the 2041 population is based on Statistics Canada's assumption of immigration levels of 150,000 per year, while the higher level is based on immigration of 330,000 annually. Sustaining the current level of approximately 250,000 will result in a 2020 population of 36.8 million and 2041 population of 43 million. Fertility and other factors will remain constant.

The structure of the Canadian population will change substantially. The current 'age dependency ratio' (the number of children and elderly to the number of people in the working population) shifts from the current low level of 48% to 64% by the year 2041. This shift is caused by the ageing of the current baby-boom population and their shifting out of the working population, and the increasing numbers in the younger population brackets.

Under Statistics Canada's middle range assumptions for immigration (230,00 per year), 62% of the population will continue to live in CMAs to the year 2041. Toronto (and vicinity), Calgary, Edmonton, and Vancouver will grow steadily. By 2041,Toronto is forecast to grow from 4.8 population to 7.2 million and Vancouver from 2.1 to 3.4 million (50 % and 60% increases respectively). Montreal will stay at about 3.4 million.

Economic Projections for Canada

The main source of economic information came from the October, 1998 report 'A Comparison of Canadian Long-term Economic Projections', provided by the Economic Analysis and Forecasting Division of Finance Canada. The report summarised the forecasts of four outside economic research organisations as well as their own internal forecast of the economy. The four outside forecasters were Informetrica (to 2025), DRI (to 2020), the Conference Board (to 2015), and the University of Toronto to 2015). The Department of Finance's own forecast provides data to 2030.

While somewhat different in structural details, there are several common elements amongst the forecasts provided. These include:

- a shrinking labour force source
- declining labour productivity
- declining investment growth
- declining capital/labour ratios
- generally a stronger service sector growth rate than that of the manufacturing sector.

When averaged, the five forecasts in the report show economic growth falling from 2.6% in 1997-99 to 1.6% by 2030. (Finance Canada's projection, shows growth falling to 1% by 2017, and remaining flat through to 2030.)

While these projections were developed more recently and are lower than the 2.2% for the same period used in 'Canada's Energy Outlook 1996-2020' they do show similar trends. Granted, the impacts of recent events in the global economy of the past six months have yet to be factored into any available forecast.

Assumptions for ETF Beyond 2020

In general, ETF will use conservative assumptions for demographic and economic growth in the period 2030 to 2050. The demographic and economic trends are the most important for the project, as it is not a model development exercise. Some important assumptions for ETF are:

- Canada's population will grow to 43 million by 2041(using Statistics Canada's assumption that immigration will be in the middle range of 230,000 net per year).
- The age dependency ratio will shift to 64%.
- The proportion of people living in CMAs (Census Metropolitan Areas) will continue at about 62%.
- Continued strong population growth in major urban centres (Toronto and Vancouver of note)
- Economic growth will peak around 2010 and decline thereafter to slightly less than 2%. (Notionally, the rate of economic growth is roughly twice that of population growth.) The economic growth rate could rebound to as high as 3% in the period 2020-40 depending on Canada's ability to develop and capture the value of new technologies and global investment in climate change and other global development opportunities a shrinking labour force source
- Major characteristics of the economy could include:
- declining investment growth
- declining capital/labour ratios
- slightly stronger growth in the service sector

There are two key variables that need close monitoring as any significant changes in them may impact on the demographic and economic context for the ETF project. These unknowns are:

- the level of immigration and its economic and energy implications
- the impacts of technology innovation and adoption and its impact on economic growth and productivity.

Potential Future Challenges for Energy Technologies

The projected decline in economic growth post 2010 will decrease the capacity to invest in the development of new energy technologies, bring them to market and pay for the replacement or conversion of capital stock.

The 50% increase in Canada's population to 43 million by 2041 will probably be among the highest rates of population growth among OECD countries. That growth will result in equivalent pressure on GHG emissions and re-enforce the necessity of de-coupling them from economic growth.

Population structure changing to a 64% dependency ratio will raise requirements for new (or conversion of) capital stock for accommodation and services.

The growth of population in Toronto and other major CMAs increases the pressure on developing and putting in place more integrated 'urban' energy technologies for buildings, infrastructure, and transportation.

The above challenges may fuel a period of intense economic transition and growth similar to that experienced in the middle of the 20th century.

OUT OF THE BOX AND INTO THE FUTURE

ETF 2030 Futures Technology Workshop
August 24, 25, 1998
Aylmer, Québec

PURPOSE

The one and a half-day workshop brought together 30 participants from the USA, Canada, and the UK in each of the four enabling technology areas:

- materials
- integrated processes and manufacturing
- biotechnology
- CO_2 management

The workshop was focused on technology idea development and integration–not the management of science and technology or policy and programs to implement technology. Experts discussed the above broad technology areas, and were able to:

- identify key enabling technologies in the areas
- develop ideas for their potential application and benefit
- develop ideas for their integration with other technologies; and
- identified priorities for development

The participants were asked to:

- Brainstorm a wide range of ideas (including expert fantasy and hunch) for the technologies which might enable other energy technologies to produce breakthrough' results in reducing GHG emissions.
- Discuss and identify potential linkages with other technologies, particularly potential valuable (in GHG reduction terms) 'downstream' technologies that could be enabled by these technologies.
- Develop a short list of technologies, and for each of the technologies develop;
    i. ideas for their potential application and benefit
    ii. ideas for their integration and instigation of other technologies
    iii. key issues and obstacles to overcome
    iv. ideas for the R&D process, partners, strategy, etc.
    v. send more ideas to other teams via 'exchange boards' in the plenary session.
- Develop a 4 chart presentation for the final plenary session primarily based on diagrams, which summarises, finds the essence and fills in the results of the team's work.

Conclusions & Observations

This section of the paper presents the common themes and conclusions reached by the four working groups. In general several key, overview conclusions were reached.

- Canadians will continue to demand clean, cheap and abundant energy supplies.
- We are in the midst of a fossil fuel driven energy economy; the transition from which will be a lengthy one that must result in an energy system with substantially reduced GHG emissions.
- Fossil fuels will continued to be used, and should not be abandoned; they should be used more efficiently and be environmentally cleaner.
- R&D and technology innovation must be started now, and continue, if we are to successfully deploy innovative, GHG reducing technologies on a broad scale by the 2050 period and beyond.
- ETF scenarios need to show an evolving mix of fuels (including fossil fuels) and service technologies as opposed to one dominant fuel or technology. Hydrogen and solar could be key end points in that evolution.
- Sequestration of carbon dioxide is a viable technology, but it must be permanent, safe, cheap, of sufficient magnitude to matter, and leave no legacy.
- Many new and innovative technologies are dependent on advances in materials and biotechnologies.

Themes of the working group reports could be categorised into four broad areas: energy supply, the way we could live, the way we could work, and key crosscutting technologies. The groups and plenary discussion also raised several cautions or other issues that could affect reductions in GHG emissions. Each of these will be discussed in turn.

Energy Supply

In the time frame to 2030 and beyond, participants saw a high probability of a hydrogen and solar based energy economy. Also they did not rule out the role that nuclear power (new generation fission, or even fusion) might play in this time frame. There was a clear recognition that Canada is in a long-term transition process of moving from a fossil based energy economy to one based on methane, and ultimately to hydrogen. As this transition unfolds, technologies will be required to increase the GHG cleanliness of interim methods of power production; e.g., CO_2 capture, disposal, management, and use of CO_2, biotechnologies, and energy storage.

Sources of hydrogen in the future could include fossil fuels, nuclear electricity generation, solar, and electrochemical processes. However, stable systems for hydrogen generation and storage and an effective and safe distribution infrastructure will be needed.

Solar energy could be supplied by space based systems, but space powered solar will need an effective and safe means of wireless transmission as well as light weight and durable PV cells.

The Way We Could Live

The emphasis on clean, abundant and reliable energy sources carries over to the home and personal mobility aspects of a 2030 environment. Participants generally saw the need to adopt a smart, flexible, and modular approach to living that may or may not include localized energy sources with minimal transmission losses. Doing so implies the development of smart and intelligent buildings and systems for personal transport and commuting. Power supplies for the home and the personal vehicle could be integrated, through, for example, a stationary hydrogen powered fuel cell providing the space conditioning and lighting needs for the home, while a mobile fuel cell would provide the power for a multi-use electric fuel cell vehicle. The hydrogen could be in a gaseous form, but more likely in a liquid or cartridge form.

The role of hydrogen in the transportation sector was very prominent with participants seeing the need to design efficient and cleaner transportation systems for vehicles (personal and mass transit), rail, sea, and air. Included in this is the need for broader based infrastructure to support the distribution, storage, and fuelling of such vehicles.

The Way We Could Work

The work place over the period to 2030-2050 could be altered by greater emphasis on the home office. This would build on the advances in computing and communication technologies, and would lead to less commuting to densely populated, energy inefficient office buildings. On the industrial side, smarter manufacturing process would be put in place and grounded in a more systems approach to production; process step elimination and process optimization; with 'just-in-time' manufacturing being the norm. Rapid technology prototyping and greater reliance on computer aided, one step product design (i.e., integrating material design, and physical design) will evolve in the manufacturing sector. More efficient goods storage and distribution processes (possibly inter-city distribution using MagLev rail) would also be dominant.

Crosscutting Technologies

Materials and processes including biological were seen to be truly crosscutting enabling technologies. The ability to achieve process and product optimization in the industrial sector depends on the development of cost-effective advanced, smart, and intelligent materials. This is also the case for the design of the components for energy efficient and intelligent buildings and vehicle systems. Development of 'green' components, where material and process design have been optimized to produce the most energy efficient product possible, could also be applied in chemical, electromagnetic, mechanical, and biological processes or any combination thereof (biomechanical, electrochemical, etc.).

Cautions and Other Issues

Participants identified several issues that could mitigate achievements in GHG reductions in the future. These included:

- Policy and science must work hand in hand, recognising the continuous feedback between them.
- Appropriate social, political, economic and regulatory frameworks are required to encourage technology innovation and acceptance. Governments need to provide the early signals to start a technology horse race. A phased in approach will allow for political acceptance and economic adjustment.
- Consumer appeal and acceptance to new technologies are necessary. Development of a sustainable attitude of innovation and product acceptance is best developed through public awareness and confidence. The public must be brought along in the process.
- Lifestyle and behavioural change may be required to achieve GHG stabilisation.
- Energy forms that use and can rely on the existing infrastructure (or one similar to it) will initially have a greater natural advantage over ones that need to re-build that infrastructure, or require a new one.
- Technology breakthroughs happen, ETF scenarios should be flexible to take these into account.
- Better understanding of the science of climate change (GHG verification, measurement, GHG cycles, and fate) are as important as enabling technologies in a carbon constrained environment.
- Do not be fooled by non-linear technology development; technologies such as biotechnologies are currently a slow starter (currently seen as fossil fuel substitutes) but could easily be a long-term winner (possible applications in refining, material production, H_2, CH_4 & oil sands production, and others)

SUMMARY REPORT OF THE ETF
BUILDING TECHNOLOGY FOCUS GROUP
November 4, 1998,
National Research Council
Ottawa, Ontario

PURPOSE

The purpose of the focus group was to:

- Develop a vision of the building technology in a GHG reducing (or neutral) environment.
- Identify possible building technologies that could be used in the 2030-2050 time frame.
- Describe the R&D priorities, technical gaps, and critical technologies for the area.

Building Technology in the 2030 – 2050 time frame

The focus group viewed the area of building science as a "taker of technology" from other areas. Two of the main reasons for this are the slow capital turnover for buildings and the high initial investment required in their construction. The structures being built today will probably still exist in the 2030 – 2050 time frame.

The following were seen as factors that could influence the design and operation of buildings over the longer term:

Energy Conservation

The focus group felt future energy demand could be much lower because of better materials, fenestration, and appliances. Super insulative materials and a recirculated building air mass could minimise energy inputs. Smart and intelligent buildings could use sensors to monitor and maintain a sealed building envelope to prevent air leakage.

Passive solar and solar thermal strategies in natural lighting, ventilation, and water heating could also assist in more energy efficient design. Advanced materials such as crystal-structure or phase change materials could be used in the wallboards and flooring to capture and gradually release heat for temperature stabilisation.

Better methods of recycling waste heat could enable more effective energy use. Waste heat from previously used "gray water" and appliances could be used in low-grade applications before being released to the outside environment. Excess heat could be

eliminated from lighting systems by photoluminescent wall lighting or fibre optic light piping distributing illumination to the building from a single light source.

Urban Form

The focus group thought that changes in population densities and lifestyles could also effect building advances. Urban areas could become more decentralized with structures clustered around local power generation and waste reclamation facilities.

Power generation could use cogeneration and provide district heating and cooling to each cluster of structures. Buildings themselves could even become net producers of energy through the use of integrated photovoltaics, wind, and other renewable forms of energy.

These urban clusters could be connected to a larger grid. A product like electricity may be traded and shared by different clusters. Over a large area, this could mitigate the variable production nature of solar and wind power and the variable demand of building occupants during a day. This may take on the form of a global energy network, an "Energy Internet".

Environmental Control

System integration and digital technology could be one of the ways to effectively manage and customise building energy needs. Smart and intelligent homes with sensors could be able to identify and possibly repair leaks in the building envelope. These buildings could also record and develop energy use patterns to better match heating/cooling, lighting and hot water needs to the building occupants. Intelligent houses could use telecommunication technologies to manage energy needs according to forecast changes in the outside environment. Energy could be saved and consumption peaks could be flattened by better managing available energy.

Flexibility

Wireless communication and energy transfer could allow buildings to become more flexible. Building space could be designed to adapt to different needs through moveable interior walls and adjustable heating and cooling systems. Energy efficient appliances could also run on high capacity batteries to make them more portable. This could allow for the rearrangement of rooms and items throughout a building in a small period of time. Public and office buildings with multiple purposes could be used all-day and year-round serving many different occupants.

Pollution

Another driver identified by the group was the control and elimination of pollution, which includes compounds produced outside and within buildings. Incorporating renewable energy systems could provide a source of emission free energy. On site energy production could use cleanse emissions to reduce pollution or use non-polluting means such as the hydrogen fuel cell. Pollutants in the building air and excess carbon dioxide could be managed through the use of biologically based purification/revitalisation systems.

Preparing Canada for Building Technology in 2030 – 2050

Developing a knowledgeable and receptive population would greatly accelerate the adoption of better technologies. Many environmentally friendly technologies exist at this time, however, their high costs prohibit wide spread application. The building industry is highly competitive and most consumers want the cheapest initial cost possible when buying a home or building office space.

The technology options outlined by the focus group require technology advancements in artificial intelligence and expert systems, information management controls, sensors, new energy storage materials (heat, light, and electricity), luminescent wall coverings, fibre optics, waste management techniques, miniaturization, and advanced materials.

ATTENDEES:

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Bill Eggartson, Executive Director, Canadian Earth Energy Association
Skip Hayden, ETB/CETC, NRCan
Jean Paquette, Manager, Energy Efficiency Program, CEDRL, NRCan
Mark Riley, Manager, BET, CETC, NRCan
Jim Robar, Manager, Housing Technology, CMHC
John Shaw, Acting Director, Indoor Environment, NRC
Frank Szadkowski, ETB/CETC, NRCan
Gerald Van Decker, ETB/CETC, NRCan
Joseph Zulak, Illumination Engineering Specialist, PWGSC

Attachment

Building Technology Cards

Energy Conservation

- Less energy demand through better insulating and airtight materials, fenestration, and appliances
- Gradual heat capture and release in walls and floors for a more stable indoor temperature through phase change, crystal pattern change, or high heat capacity materials
- Moisture control to modify humidity to minimize heating expenses while maintains a minimal comfort level
- Photo-luminescent fixtures or paint by chemical or biochemical means
- Fibre optic lighting to avoid excess heat creation
- Micro-friction materials for moving parts
- Biologically derived insulation
- Bioluminescent materials

Urban Form

- Collections of structures in sustainability zones in which resources and waste are processed on site
- Energy neutral or producing and pollutant neutral or consuming buildings
- Distributed and decentralized services and infrastructures such as solid waste management, sewage treatment, and drinking water
- Carbon fibre reinforced structural materials for high strength and light weight

Environmental Control

- Building residents having complete control over their environments
- Integration of appliances, lighting, space conditioning, and transportation requirements through a centralized controller/optimizer
- Internet connection for an intelligent house to anticipate temperature drops and weather changes

Flexibility

- Multiple source adaptability in stationary fuel cells for electricity and heating needs
- Transmitted power and communications for a wireless environment
- Multiple use buildings with flexible rooms for day long and year long usage
- Small, long life, high capacity batteries for appliances and electronics

Pollution

- Using building materials that do not release pollutants while degrading
- Biological purification and revitalization of building air in a closed system
- Onsite production of electricity using renewable energy sources like wind and solar power
- Onsite heating and cooling using geothermal or hydrothermal technology
- Biomass co-generation from local feedstocks
- Passive solar and solar thermal applications for light and heating of air and water
- Stationary fuel cells for on site electricity and heat generation

SUMMARY REPORT OF THE ETF
HYDROGEN FOCUS GROUP
November 14, 1998,
British Columbia Institute of Technology
Vancouver B.C.

PURPOSE

The purpose of the workshop was to:

- Identify the potential role that hydrogen could play in the energy economy in the 2030-2050 period;
- Identify key hydrogen technologies that could play an important role in that timeframe; and
- Identify the R&D priorities, technology gaps, and the technological barriers to the implementation of these key technologies.

HYDROGEN'S LONG-TERM ROLE

Electricity could still be the prime energy carrier 2030-2050 because it is the most valuable and flexible, form of energy for society. Like electricity, hydrogen is a premium quality energy carrier, which can be used with very high efficiency and zero emissions. However, it is more than a carrier, it is both an energy distribution and storage system. Fuel cells and electrolysis are necessary for neutral conversion of electrical energy and hydrogen. The group felt that hydrogen could be the primary energy source for most of the future energy service needs in the future. Issues of production, storage and transmission were raised as key areas for further consideration.

HYDROGEN PRODUCTION

Hydrogen can be produced from any energy source and many different feedstocks. However, the emissions associated with the amount of energy used in the hydrogen production process vary significantly. By way of illustration: the use of compressed hydrogen from water electrolysis, (using nuclear power or a renewable source) offers an 80-90% reduction in emissions of GHGs, whereas the use of liquid hydrogen made from water electrolysis only offers a 50%-60% GHG reduction. The use of compressed hydrogen from natural gas offers only a 30% reduction in GHGs, and the use of liquid hydrogen from natural gas offers essentially no GHG benefits.

Some of the non-fossil energy sources that could be considered in the long-term are: space-based solar, highly focused solar, nuclear fission, cold fusion. energy from other planets, hydropower, geothermal energy or wind energy.

Some of the hydrogen production processes that could be considered are electrolysis, partial oxidation, steam methane reforming of natural gas, biomass etc., anaerobic direct generation of hydrogen, reverse fuel cell, photoelectrochemical cell, plasma-arc hydrocarbon splitting, by-product of industrial processes.

Two long-term, low-energy hydrogen production processes that hold potential are direct conversion of biomass to hydrogen, because it bypasses the electricity step; and direct sunlight methods where photon-catalysed hydrogen production occurs without involving electrolysis.

Often, hydrogen has to be purified before it is used. The catalysts and membranes of fuel cells are extremely sensitive to contaminants: contaminants reduce the operating life of fuel cells substantially. Current and future purification techniques could rely on membranes or chemical and physical adsorption (such as pressure swing absorption).

HYDROGEN STORAGE AND TRANSMISSION

A storage approach for hydrogen is needed that can preserve hydrogen's lightweight and energetic qualities and minimise its bulky nature. Currently, hydrogen can be stored as a compressed gas, as a liquid or slush, or in the form of a solid–either as a metal hydride, adsorbed/absorbed onto carbon (nanotubes, fullerines, activated carbon) or in glass microspheres.

Suggested transportation techniques: pipelines or compressed fuel containers for gaseous hydrogen, pipelines (short distance) or tankers for liquid hydrogen, teleportation (beam), biophysical/biological means, organic transporters, materials containing hydrogen from which it be released easily

USES FOR HYDROGEN AS A CLEAN ENERGY CURRENCY

The use of hydrogen as a clean energy technology was enabled by the development of the fuel cell. Hydrogen can be used for thermal and electrochemical conversion processes, as a fuel for transport, for home/stationary use or for military use.

POSSIBLE HYDROGEN FUTURE

The group also developed a view of a possible hydrogen future as well as a set of technologies for the future. The scenario developed is based on the emergence of smaller, more integrated energy systems using "distributed power generation" that could eliminate the need for transmission of hydrogen.

Electricity from these local sources could top-up the energy needs of "smart" houses that could be equipped with solar capture facilities, perhaps photo-electrochemical cells, electrolysers, fuel cells and hydrogen appliances. Each home could use electricity and hydrogen. It could have its own electrolyser unit requiring water and electricity to produce hydrogen for household appliances and personal vehicles. A fuel cell running on hydrogen could run in cogeneration mode providing heat and electricity for the home. If the fuel cell had excess capacity it could feed into the grid. If reversible fuel cell technology was adequate, electrolysers would not be needed and either the home or the car could be run from reversible fuel cells. Industry too, could be able to operate on a similar model, using local clean energy sources, and fuel cells to power production plants.

OVERALL TOP-RANKED TECHNOLOGIES

The group developed a list of the key hydrogen technologies that could play an important role in the long-term hydrogen future. They then ranked these, with the following emerging as the key hydrogen technology issues.

- Lightweight, rapid adsorption/release, high-energy density materials for transportation
- Reversible fuel cells for use in cars, ships etc.
- A process to develop hydrogen from nuclear sources, having solved the problems of nuclear waste
- Develop slush hydrogen, superconducting magnets etc. for hydrogen storage
- Develop storage technologies for gaseous/liquid fuels in general. Develop hybrid systems using fuel cells, gas turbines, new hydrid fuels (e.g. diesel plus hydrogen fuel-98% diesel, 2% hydrogen or vice versa depending on the load for use in a 50% efficient engine, ensure that particulates have been removed-particulates < 2 microns are considered carcinogenic)
- Develop electrochemical methodology for reduction of carbon dioxide emissions
- Develop intelligent controls for mobile/residential power sources

ATTENDEES:

Prof. John Barclay, Cryofuels Systems Group, Department of Mechanical Engineering, University of Victoria
Joachim G. Borck, Senior Technologist, Daimler-Ballard Benz Fuel Cell Engines Inc.
Stephen Brydon, Strategic Industries Branch, B.C. Trade and Investment Office, British Columbia Ministry of Employment and Investment
Dr. Stephen Campbell, Senior Scientist, Core Technology, Ballard Power Systems
Paul Howard, Consultant and Founder Member, Ballard Power Systems
Dr. R. Ellis Knowlton, Manager, HAZOP and Consultancy Services, Kvaerner Canada Inc.
Pierre Rivard P.Eng,, President, Hydrogenics Corp., Toronto
David Shepherd, Senior Analyst, Science and Technology Branch, British Columbia Information, Science and Technology Agency
Dr. Jurgen Stumper, Senior Scientist, Core Technology, Ballard Power Systems
Colin Oloman, Professor of Chemical Engineering, Dept. Chemical and Bio-resource Engineering, University of British Columbia

Attachment

KEY HYDROGEN TECHNOLOGIES 2030-2050

Hydrogen Production Technologies

- Steam methane reforming
- Partial oxidation
- Electrolysis of water
- Direct hydrocarbon splitting
- Thermochemical splitting of water
- Photochemical/photoelectrochemical means
- Photobiological processes
- Indirect production from biomass
- By-product of chemical manufacturing/petroleum refining

Hydrogen Storage

Compressed gas for on-board vehicle storage (personal vehicles, mass transit, aircraft, hyperplanes, rocket fuel) and for stationary use (mass storage and for niche and/or remote applications).

- High pressure gas in glass microspheres
- Liquid or slush hydrogen (-253°C)
- In a hydrocarbon fuel such as methanol (A reformer is need to produce hydrogen, for transportation the reformer could be at a filling station or on-board the vehicle).
- As a metal hydride (solid but heavy)
- Adsorbed or absorbed onto/into some form of carbon (nanofibre, nanotube, fullerine, activated carbon)

Hydrogen Transportation

- Tanker as a compressed gas
- Tanker as a liquid or slush
- Pipeline-in a dedicated hydrogen pipeline system
- Pipeline-as hydrogen-spiked natural gas
- As a metal hydride
- As some form of carbon cartridge containing nanotubes, nanofibres, fullerines, activated carbon.
- Teleportation (beam)
- Biophysical/biological means
- Organic transporters (compounds)

Hydrogen Use Technologies

- Fuel cells for transportation use
- Fuel cells for stationary use
- Reversible fuel cells (would obviate need for electrolysis)
- Direct methanol (or other liquid) fuel cells – hydrogen extracted directly from the fuel without the need for a reformer. Methanol could be produced from fermentation of biomass which has a short-term carbon cycle.
- Hybrid fuels (diesel/hydrogen hybrids)

SUMMARY REPORT OF THE ETF
BIOTECHNOLOGY FOCUS GROUP
November 20, 1998,
NRC - Plant Biotechnology Institute
Saskatoon, Saskatchewan

PURPOSE

The purpose of the focus group was to:

- Develop views on the potential role of biotechnology to meet future energy needs.
- Gather ideas for the prospects of biotechnology in the 2030 - 2050 time frame.
- Identify the R&D priorities, critical paths, technology gaps, and technology barriers to implementation.

The Tools of Biotechnology

The focus group identified two areas as being important for future biotechnological development:

- Developing uses for existing or engineered organisms in specialized applications for processing or product creation.
- Developing organism/microorganism interactions to improve the functioning of plants, animals, and humans with mutually beneficial associations.

Biotechnology-Energy Linkages

Biotechnology could allow for energy related improvement in areas such as:

- In situ processing of petroleum
- Production of liquid and gaseous fuels
- Replacement for many fuel and chemical processes with substantial energy savings
- Smart and intelligent systems
- Artificial intelligence and robotics
- Bioremediation

Biotechnology Applications in the 2030 – 2050 Era

The focus group believed biotechnology could offer solutions in the following areas.

Industrial Processes

Microbial enzymes acting as catalysts could accelerate the processing and treating of certain products. During processing, biological means could be used to separate pollutants from effluent or emissions. Genetic engineering could be used to alter microbes and their enzymes to adapt to different industrial environments.

Also, biologically based sensors could also used to detect certain chemicals used in industry. They could be used to detect pollutants or other gases to help 'fine tune' processes. Biologically derived tools could be available for product synthesis or sensing and process intensification, monitoring, and control.

Green House Gas (GHG) Fixation

Longer-term fixation could be achieved as an indirect benefit of biologically derived polymers or through biomass fixation processes. Extending forested areas into marginal land or redeveloping plants to better produce biomass represents one approach. Creating other GHG fixing microbes and plants is another possibility.

Biological Computing

Artificially intelligent control systems could be designed to imitate the human brain's processes. This could create computers that think similarly to humans and are better able to make decisions with regards to energy production and use. Robots using biological/computer interfaces could be part of an array of smart and intelligent machines that use biological sensors to trigger mechanical responses.

Biomass Creation

Biomass crops could be developed that are self-fertilizing and create their own multiple defenses in lieu of herbicides and pesticides. They could also be redesigned to have more alcohol producing potential. Genetically engineered crops could also indirectly impact the energy sector by being easier to grow, containing more potential energy, or being Canadian climate tolerant varieties of currently imported crops.

Adaptive Strategies in a Warmer and Drier Climate

Crops and trees could to be genetically altered for drought and heat tolerance, higher yields, faster maturation, and improved nutrient utilization. Another strategy could be re-engineering plants to take advantage of higher carbon dioxide levels in the atmosphere.

Impacts on the Future Energy System

The focus group identified certain technologies that directly effected energy production, use, and storage. They can be grouped into the following areas.

Biofuel Products

Biofuels could be used on their own or to supplement existing fossil fuels. Fuels derived from fermentation of biomass or biodegradable municipal wastes represent potential options. Biodegradable waste could also be treated to create combustible gases and liquid fuels through the process of pyrolysis. By-products of biofuel creation can be utilized like bio-lubricants, solvents, polymers, surfactants, and emulsifiers.

Genetically altered microbes could also be used in the petroleum industry to process crude oil into shorter chained hydrocarbons like methane. This could be done while the oil is still in the ground.

Energy Production

Algae and other microorganisms could be used to produce gaseous fuels. Hydrogen could be produced by processing alcohols, glucose, or while fixing nitrogen. Other gases like methane could also be synthesised on a large scale.

Energy Use and Storage

Buildings could be self-contained with biological air purification and extensive use of living or biologically derived materials. They could use bio-engineered energy storage systems to store heat energy in the form of chemical compounds.

ATTENDEES:

Ajay Dalai, University of Saskatchewan
Malcolm Devine, AgrEvo Canada Inc.
Murray Gray, University of Alberta
Wilf Keller, Plant Biotechnology Institute
Peter Lau, BRI, NRC
Jim MacPherson, Performance Plants Inc.
Dave Minns, ICPET, NRC
Louise Nelson, Ag Biologicals Research, Agrium Inc.
Hans Peterson, WateResearch Corp.
Martin Reaney, Agriculture Canada
Gopalan Selvaraj, Plant Biotechnology Institute

Attachment

BIOTECHNOLOGY CARDS

Fuels

- Fermentation of agricultural and municipal wastes to create alcohols
- Anaerobic digestion of biodegradable waste to create methane
- Pyrolysis of biodegradable waste to create biodiesel and combustible gases
- Use of Bio-oil by-products like lubricants, solvents, surfactants, and emulsifiers
- Hydrogen producing organisms through nitrogen fixation of ammonia or methane conversion
- In situ biological processing of petroleum products to create shorter chain hydrocarbons

Climate Change Adaptation

- Altered crops and trees for drought and heat tolerance, and higher yields, faster maturation, improved nutrient utilization
- Reengineer plants to take advantage of higher CO2 levels in the atmosphere
- Biologically based life cycle analysis techniques

Agriculture

- Develop crops that self fertilize and defend themselves
- Food wastes as a raw material for biofuel, oil, or acid production
- Modifying animal feedstock or the animals themselves for more efficient food conversion and less waste
- Developing northern strains of existing southern crops

CO_2 Sequestration

- Iron seeding in oceans for algae carbon storage
- Biomass growth and conversion of carbon for long term storage
- Biomass growth on marginal lands
- Improved carbon absorbtion and retention in soil, crops, and trees
- Large scale biopolymer production

Sensors and Information Processing

- Biologically based or inspired sensors for chemical detection
- Computer technology integrated with the human body or other life forms for direct thought to action control
- DNA or other biochemically based information storage and processing
- Biologically based algorithms for expert systems and AI controllers

Remediation and Purification

- Multi-phase pollutant uptake and processing by microorganisms or genetically modified plants
- Conversion of chemical compounds by extracted enzymes
- Purification of waste streams by enzymes, microbes, and bio-membranes
- GHG conversion into solid forms by biochemical bonding

Industrial Processing

- Creation of biological processors that take incoming energy to grow and mend themselves as well as produce
- Bio-refining petroleum products in oil beds or in refineries by cracking, decarbonization, or hydrogen production
- Biocatalysts for bleaching, cleaning, chemical conversions, waste conversion and product refining
- Measurement and monitoring of compounds by biochemical means
- Bio-leaching of metals through microorganisms to extract metals in any concentration or volume
- Bioprocessing streams of products to refine them contaminants removal with selective biological membranes or filters
- Bioprocessing streams of waste for cleansing and changing the contaminants into a more desirable form through bio-fixation

Industrial Production

- Synthesis of products like polymers and other complex macromolecules for products, proteins, nucleotides, enzymes or other specialized uses
- Biochemistry replacing chemistry in mass production of simple compounds for large scale use
- Production of fibre for clothing, insulation, and specialized materials
- Microbial communities able to synthesis complex chemicals with in one vessel by eliminating process steps or performing them in parallel

SUMMARY REPORT OF THE ETF
MATERIALS AND MANUFACTURING FOCUS GROUP
November 26, 1998
Materials and Manufacturing Ontario
Mississauga, Ontario

PURPOSE

The purpose of the focus group was to develop views on the role of sustainable industrial technologies, with emphasis on materials and manufacturing systems, in the 2030 – 2050 timeframe. This included:

- Identifying prospects for GHG reducing materials and manufacturing technologies
- Identifying the R&D priorities, technology gaps, and technology barriers to the implication of these technologies

Manufacturing Systems in the 2030 – 2050 Era

The group envisioned intelligent manufacturing systems and products that could radically reduce energy consumption and GHG emissions.

Flexible and agile manufacturing systems could respond quickly to changes in consumer demands, materials, energy technologies and other market parameters. They could provide rapid continuous 'one-off' manufacturing of unique products (with tailored energy and GHG properties) as opposed to mass-produced products, and move from design to product in one step. They would be based on intensive modelling and life-cycle analysis of the product, its materials and the equivalent manufacturing technologies. These systems could operate with zero feedstock waste, closed emission systems, and recycling of energy.

Flexible manufacturing cells with fast retooling, multi-processing and rescheduling, could replace current production lines comprising chains of single-function machines. Such systems could be capable of multi-tasking and making production changes quickly and easily. Increased automation will use advanced technologies such as robotics, artificial intelligence, high-speed computing, wireless communications, power electronics and photonics. These systems could also detect and correct energy, GHG, maintenance and repair problems. Manufacturing systems could be accommodated in remotely operated 'dark factories' requiring few staff and little heating and lighting.

The group also noted the trend towards miniaturisation and how it could effect types of products and manufacturing systems. Combining micro-machines with computing power could give us the ability to manufacture small or microscopic precision devices with the ability to sense, react and communicate for applications in controls, bio-engineering, electronics and other sectors. Manufacturing processes could be developed which enable molecule-by-molecule construction of microscopic devices.

Materials in the 2030 – 2050 Era

The group thought that new materials could have a very significant impact in future products, tools and manufacturing with significant reductions in energy requirements and GHG emissions. Materials could be tailored to meet almost any product or process, use, energy, GHG, and life cycle requirements. Recently we have seen the beginnings of this in the growth in the number of new alloys, composites, polymeric materials, and hybrids that have been tailored for specific applications.

Future materials could have many built-in properties. Some material property improvements could be achieved through surface-modification or coating techniques providing self-lubricating or frictionless materials, paintless materials, self-adhering assembly, and better wear or corrosion-resistant materials. Materials could also have built-in as life cycle controls such as timed breakdown into a re-usable composition. New materials could combine biological organisms with inorganic materials. The weight of materials could be radically reduced for almost every industrial application.

Barriers & Priorities: MODELLING and Lifecycle ANALYSIS

The group developed the view that the development of the above future materials and manufacturing processes will absolutely depend on advanced modelling and lifecycle knowledge, analysis and systems. Currently many models exist for process optimization but few include the ability to select or design the materials and technologies for the process, and fewer still have any total lifecycle capability. A total modelling and lifecycle approach would include the sustainability of upstream and downstream energy sources and their use including the energy used for extraction through the manufacturing cycle, in-product use, and to the ultimate break-up, separation, recycling and re-use of the product. The group also developed an outline plan for the development of advanced modelling and life cycle analysis.

ATTENDEES:

Dr. Grant Allan, President and CEO, Materials and Manufacturing Ontario
Mike Burke, Manager, Federal Industrial Boiler Program, CETC, NRCan
Dr. Jean Bussiere, Process Instrumentation, Industrial Materials Institute, NRCC
Dr. Ed Capes , Director General, Institute for Chemical Processes and Environmental Technology, NRCC
Dr. Gopala Gowda, Industrial Technology Advisor, Industrial Research and Assistance Program, NRCC
Margaret McCuaig Johnston, Manufacturing and Processing Technologies Branch, Industry Canada
Chris Morris, Manufacturing and Processing Technology Branch, Industry Canada
Dr. Georges Salloum, Director, Process Modelling and Optimization, Industrial Materials Institute, NRCC
Dr. Bill Tyson, Group Leader, Materials Behaviour, MTL, CANMET, NRCan
Professor Ron Venter, Dean of Mechanical Engineering, University of Toronto

Attachment

Factories and Manufacturing

- Completely automated factories
- Change management systems
- On-line (Real Time) process controls
- Robotics
- Artificial intelligence
- High-speed computing
- Rapid prototyping
- Rapid re-tooling
- Multi-tasking manufacturing cells
- Wireless communications
- Photonics (involving photons - electronic imaging, lasers, semiconductors, X-ray technology, virtual reality)
- Miniaturisation
- Recycling
- Nanotechnology

Advanced Materials

- Materials selection
- Materials energy intensity
- Materials databases
- Materials characterisation
- Designing a new material and predict its properties based on its microstructure
- Self-lubricating and frictionless materials

SUMMARY OF THE ETF
Mobility Workshop
Chrysler Automotive Centre
December 4th, Windsor, Ontario

PURPOSE

The purpose of the workshop was to:

- Identify key factors that could influence the design and structure of the mobility sector in 2030-2050;
- Identify key fuels, materials, component production and assembly technologies that could play an important role in that timeframe; and
- Identify the R&D priorities, technology gaps, and the technological barriers to the implementation of these key technologies.

THE DESIGN AND STRUCTURE OF MOBILITY

LAND TRANSPORT

In response to customer demands, the group felt that personal vehicles could be similar to what they are today. There could probably be a variety of 2-6 passenger wheeled vehicles travelling on a roadbed with a cruise speed of about 100 km/h and a range between 300-500 km. Friction will likely be used as the mechanism for steering control.

RAIL

In the 2030-2050 period, it is expected that high-speed wheeled rail systems, probably electrified, could be in place in heavily populated and industrialised areas for passenger and goods transport. These trains could probably travel between 200-500 km/h and be used regularly over 200-1000 km distances.

AIR TRAVEL

Air travel could be much the same as today with perhaps increased use of high turbo fans and prop fans. They would probably fly just sub-sonically at mach 0.98 or thereabouts and be used for stage lengths greater than 1,000 km.

Technological for Personal Vehicles

The important technologies identified by the group could be categorised into three areas: propulsion systems, fuel sets and the materials and processing technologies used for parts production.

PROPULSION SYSTEMS

The view, expressed by the group was that there could still be a higher proportion of vehicles powered by internal combustion engines (ICEs) than other types of vehicles-whether fuel cell, electric or hybrid-in 2030-2050.

The group felt that hybrids would not have a high market share because they are inherently complex and suffer, for example, from decreased mechanical efficiency because they have a greater number of moving parts.

In terms of long-term emphasis the group favoured:

- ICEs based on homogeneous charge with self- or radical-ignition
- Fuel cell vehicles
- Hybrid vehicles (up to about 2010)

Electric vehicles were not considered viable because of the tremendous lifecycle energy consumption in making and disposing of batteries.

Advanced ICEs - Technologies for 2030-2050

- Engines based on homogeneous charge with self- or radical-ignition
- Control devices to improve engine performance: VVT, CVT
- Catalytic combustion
- Post-combustion catalytic reduction
- Materials development for ICEs - High temperature ceramic engines, frictionless materials

Alternative propulsion systems

Engines other than four stroke or diesel exist: rotary; advanced two stroke; turbine; Stirling; low-heat rejection diesel etc. Different hybrid electricity-fuel vehicles exist with differing emphasis: batteries and grid energy; fuel energy, engine operates near optimum, batteries used for storage; or fuel energy, but with "power storage" equipment (flywheels or capacitors). Electric vehicles exist that use different types of batteries: advanced lead acid; nickel cadmium; nickel-metal hydride; sodium sulphur etc.

Fuel Cells

Fuel cells are an important, rapidly evolving technology. Fuel cell vehicles are fuel-based and electrically operated. In contrast to an internal combustion engine, fuel cells convert energy into power by electrochemical rather than thermo-mechanical means. They offer a propulsion system with zero-emissions.

A number of different fuel cell designs exist, each with a different set of advantages, disadvantages and applications. The most promising for light vehicle use are primarily proton exchange membrane (PEM) fuel cells. PEM fuel cells are compact and operate at low temperatures. However, there are some challenges to overcome.

FUEL SETS

In early seventies, during the energy crisis, energy security was the main driver. Today environmental concerns are the driving forces. In 2050, the group thought that security of supply could be the main issue again.

In terms of energy and power density, there is a hierarchy of fuels. Gasoline and diesel have the highest power density followed by alcohols (methanol/ethanol etc.), natural gas, propane and hydrogen respectively.

The group place emphasis on development of reformulated liquid, high-energy density fuels such as reformulated gasoline, hybrid fuels such as hydrogen mixes followed by all alternative fuels. The group felt that some effort should be devoted to in-vehicle and at source carbon capture technologies.

Materials and Manufacturing Technologies

The energy consumed in producing a car is equivalent to 4.5 years of operation for the average vehicle. This emphasises the importance of lifecycle analysis modelling to minimise GHG emissions and energy consumption during production.

Examples of materials for the automotive industry of the future

- lightweight and crashworthy materials: low weight, low energy input, low cost e.g. high-strength steel; aluminium and magnesium, plastic composites
- advanced alloys that change viscosity with changing current - their damping factors and spring constants change -this can be used to advantage in can be used in springs, suspension systems or clutches
- composites - metal matrix, polymeric, plastic -composites are designed to combine two dissimilar materials (metals and non-metals in the case of a metal matrix composite) to produce a high-performance material with the best properties of both and none of the worst
- crack-resistant, high-temperature ceramic materials for engines
- hybrid materials-layered materials
- surface modified materials-for example:
- self-lubricating or frictionless materials to render lubricants obsolete and reduce component wear
- paintless materials-use of surface modification techniques to produce corrosion-resistant materials that can be coloured to specification and do not need to be painted

- nano-modified (atomic-scale construction) material surfaces for niche application such as increased wear resistance or electrical conductivity, other surface modification techniques such as ion implantation could become increasingly important also
- smart and intelligent materials with built-in sensor and actuator mechanisms
- shape memory alloys that reconfigure into their original shape after deformation.

Infrastructure issues

Electricity generation was seen as an issue. Nuclear power was addressed as being a viable way of producing power for stationary use. Effective radioactive waste and heat disposal as well as a change in public perception of the nuclear industry would be required. Even so, overhead issues were seen as limiting the role of nuclear.

A new fuel infrastructure may have to be considered if, for example, hydrogen becomes the fuel of choice in the long-term.

Road improvements and new roads are needed; high-speed commuter and goods rail links are needed.

CO_2 sequestration at power plants and factories need to be addressed in addition to focusing some effort on on-board vehicular sequestration.

Details on the technology areas identified by the group are attached.

ATTENDEES:

John Mann, Director of Engineering, Daimler Chrysler Canada
Jim Lanigan, Product Development Manager, Daimler Chrysler Canada;
Peter Frise, Daimler Chrysler Chair in Mechanical Design, University of Windsor, and
Andrzej Sobiesiak, Daimler Chrysler Chair in Alternative Fuels, University of Windsor.
Professor J. Douglas Boyd, Queen's University, Kingston, and
Professor Marc Ross, University of Michigan

Attachment

INFRASTRUCTURE

- Smart highway systems, crash avoidance systems
- Road improvements
- High speed rail links
- Nuclear research to provide energy for stationary use
- Fuel infrastructure for alternative fuels such as hydrogen
- On-site carbon dioxide sequestration at power plants, factories etc.

PERSONAL VEHICLES

Propulsion Technologies

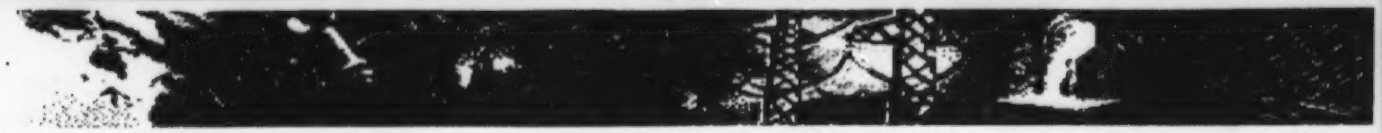
- Internal combustion engines
- Engines based on homogeneous charge with self- or radical-ignition
- Control devices to improve engine performance: VVT, CVT
- Catalytic combustion
- Post-combustion catalytic reduction
- Advanced Materials development for ICEs
- Fuel cells and hydrogen storage

Fuel Sets, Carbon Management

- high energy density reformulated liquid fuels such as designer gasoline
- hybrid fuels e.g. hydrogen and gasoline, hydrogen and diesel
- other alternative fuels
- on board CO_2 capture

Materials and Manufacturing

- Greatly increased use of simulation
- Materials/process/part design integration
- Modelling of material engineering properties through microstructural control
- Computational fluid dynamics (CFD): integration of air flow, heat flow and combustion, overall vehicle aerodynamics
- Design of manufacturing and assembly techniques
- Power electronics for systems control
- Rapid prototyping primarily for die manufacture
- Designer Materials
- Lightweight and crashworthy materials
- High temperature, crack-resistant ceramics for lightweight engines
- Advanced alloys, hybrid materials, composites
- Smart and intelligent materials
- Self-lubricating (frictionless) materials, paintless materials, materials with electro-rheological properties, shape memory alloys etc.



SUMMARY REPORT OF THE ETF
HYDROCARBON FOCUS GROUP
December 15, 1998,
Alberta Department of Energy,
Calgary Alberta

PURPOSE

The charge to the group was to develop long term scenarios (2050) for a sustainable hydrocarbon energy system. Each participant was asked to envision:

- What the hydrocarbon economy could look like in 2050?
- What technologies, including CO_2 capture and disposal would be required to make the hydrocarbon industry greenhouse gas (GHG) neutral?
- How and over what timeframe could these technologies evolve?

HYDROCARBON CONDITIONS IN 2050

By the year 2050, the state of the industry could be very similar to that of today.

- Canada could continue to be a world producer of hydrocarbons,
- energy consumption patterns will not likely change dramatically, and
- Canadians will continue to demand and use our existing "liquid fuels" infrastructure.

Sources of supply of Canadian hydrocarbons could become more remote, and somewhat more energy intensive. Oil from conventional wells currently non-producing could become viable given the growing use of CO_2 injection (the value of CO_2 disposal in wells could make these sources more economic than they are currently). In addition, the energy production and distribution systems could be collapsed and merged for greater efficiency.

The significant investment in fuel cells could start to pay off in their application in distributed power systems. Coal could continue to play a major role in the energy system particularly in the use of CO_2 storage for the production of coal-bed methane, or through the gasification of coal to liquid fuels (including electrochemical separation).

Natural gas could remain an important source either in direct applications or through the production of syngas. Natural gas, while cleaner than other hydrocarbon fuels, should have a premium, and its use should match this higher value; i.e., natural gas should not be used as a bridging fuel or in point sources (electricity production). In additional non-producing natural gas wells could be used for CO_2 storage over the longer term.

Consumers will still demand the services from energy that are seen today. This service demand focus will allow newer technologies to be more effectively and more widely applied. This can particularly be the case with the application of bio technologies to produce designer liquid fuels that match the liquid fuel requirements of consumers while meeting the quality demands from, say, the automobile industry for use in their newer designed engines. Similar biotechnology applications such as the insitu anaerobic production of hydrogen for H_2S, or the bioprocessing of oil sands and heavy oils may also be possible.

SEQUESTRATION OF CO_2

Sequestration of CO_2, especially into fixed energy sources, is the essential ingredient in the development of a sustainable hydrocarbon system. There are large potentials for sequestration in the oil patch, agriculture, forestry, and ocean sectors. Key to the sequestration issue is the need for better separation technologies (fundamental enabling technologies). In this context as well is the need for membranes for chemical feedstock applications.

DISTRIBUTED ENERGY SYSTEMS

Growing electrification of the economy will require varied sources of supply, reliance on superconductivity (simple and cost-effective), and energy storage systems possibly Electro-magnetic) to manage supplies on response to loads.

Standalone systems could be replaced by more distributed ones, and more integrated energy complexes, with on-site production from these "energy plexes" supplying the needs of smaller users. The "plexes" could be co-fired systems using coal, biomass, and other fuels, or ceramic fuels cells. These systems could also be using better separation technologies to ensure the capture of CO_2 produced for subsequent storage.

More efficient distribution systems could change the economics and nature of transporting electricity, and could lead to having to make more fundamental infrastructure decisions.

Nuclear fission and fusion could have a huge future, but overhead costs could severely limit the role that this source could have.

The Group also envisioned the future Canadian economy consisting of two distinct, but necessary types of society – the Green Society and the Consuming Society. Both of these societies could exist and each is reliant on the other.

The Green Society is a more centralised urban society that relies greatly on advanced communications (e.g. tele-commuting, tele-medicine) and a mass public transportation system. It relies on localised solutions and personal choice is important. Industry tends to be light and distributed.

The Consuming Society is characterised by continued urban sprawl. Society continues to value personal mobility, but demands highly efficient vehicles. Society demands the cleanest, cheapest and most reliable energy source. Individuals look to industry and government for centralised solutions. Economic growth is emphasised. Industry tends to be large scale and integrated, with a greater emphasis on energy utilisation (i.e., co-generation, networked and by-product synergies).

CONCLUSION

It was agreed that such discussions regarding the future of role of hydrocarbons in a sustainable energy economy are essential. Hydrocarbons are an important part of the Canadian economy and as such our wealth and dependence on them should not embarrass us. Rather, Canada should learn to use then smarter and cleaner – in a sustainable manner. Given our vast knowledge, Canada could strive to develop and adopt clean hydrocarbon technologies.

ATTENDEES:

Allan Amey, Technologies and Assessment, TransCanada Pipelines
Roger Bailey, Director, Research and Technology Branch, Alberta Department of Energy
Graham Boje, Shell Canada
Amit Chakma, Dean, Faculty of Engineering, University of Regina
Daphne Cheel, Science Advisor, Alberta Science and Research Authority
Pietro Di Zanno, Marketing Manager, Chemical and Refining Industries, Air Liquide
William D. Gunter, Environmental Technologies, Alberta Research Council
Linton Kulac, Director, Health, Safety and Environment, Shell Canada Limited
Malcolm McDonald, Head of Research and Development, TransAlta
John Oxenford, Responsible for R& D Strategy, Syncrude
Mike Singleton, Process Development Oil Sands Sustainable Growth, Suncor Energy
Bruce Stewart, Director, CANMET Western Research Centre, NRCan
Malcolm Wilson, Resources Policy and Economics Division, Saskatchewan Energy and Mines
Dr. C.S. Wong, Climate Chemistry Laboratory, Fisheries and Oceans Canada
Paul W. Young, Environmental Programs, Petro-Canada

Attachment

Fossil Fuel Decarbonisation

- Carbon dioxide separation, hydrogen separation or purification
- Gas membrane separation technologies
- Biological processes - methane producing bacteria

Carbon Dioxide Capture

- Chemical solvents designer & membranes
- Biological fixation
- Oxygen combustion - (cheap O2)
- Cryogenic distillation of carbon dioxide
- Molecular sieves
- From hydrates

Carbon Dioxide Disposal

- Ocean sequestration
- Aquifer storage
- O&G EOR
- CO2 solid disposal - carbon black (thermal decomposition), dry ice

Carbon Dioxide Utilisation

- Feedstock for chemical processes
- Acceleration of crop & foods growth
- EOR
- CBM

Electricity

- IGCC III - low NOx low CO2 using advanced materials
- Stationary fuel cell/turbine hybrids
- Biomass/coal co-firing
- Ceramic fuel cells
- Emergence of energy plexes - large industrial complexes serving electricity needs of small units
- Energy storage
- SMES
- Batteries
- Flywheel
- Chemical

Fossils

- Acid gas solvents for HO/OS production
- Bioprocessing of HO/OS
- Biodesigned fuels
- Super fuels
- Hydrogen Diesel

Natural Gas

- CBM
- NG decarbonisation
- Syngas from coal, residues, and gasification
- Underground coal gasification
- Gas hydrates as a source of NG
- In situ gas disassociation

SUSTAINABLE TORONTO FOCUS GROUP,
January 18, 1999
Toronto, Ontario

PURPOSE

The purpose of the meeting in Toronto was to explore the views of Toronto regional planning officials in:

- The major shifts in municipal infrastructure technologies to 2050.
- Priorities for "municipal energy technologies"
- Knowledge & innovation needs.
- Other studies in similar time frame.
- Potential linkages/joint ventures amongst stakeholders.

According to StatCan's middle range forecast, the population of Toronto could double to over seven million by 2041. The cities of south-western Ontario from Oshawa, through Toronto to Niagara, London and Windsor could add up to approximately 20 million of Canada's total population of 41 million in 2041.

Today, Toronto is facing critical issues in traffic congestion and air pollution, housing shortages and the social and energy costs of suburban sprawl. Ridership on public transit is shrinking.

Trends and plans for the '905' area around Toronto are almost exclusively focused on highways and 'sport utility' vehicles. The City of Toronto has recently had several municipalities added to it by the Ontario government. Most current planning is devoted to 're-organisation' rather than strategic outlook beyond the five-year horizon.

The issue for discussion was how the region saw itself managing this burgeoning population by the 2040-2050 period, as well as the climate change issues that would be associated with this growth.

Currently, there are two significant projects underway that could help reduce GHG's.

- The conversion of cooling systems in the downtown core to cooling with deep lake water (with a 90% reduction in energy use)
- A continuing effort to regulate high building energy efficiency

There were views that Toronto's ageing inner city population could be seeking a more 'urbane' pedestrian friendly and personal service oriented life style as they retire and go through old age in the 2015 - 2040 period.

The focus group produced some ideas for a more sustainable city in the 2030-50 as follows:

i. Expand the use of lake water for cooling and heating using 'temperature gradient' technologies.

ii. Reduce waste eliminate land-file and convert all waste into heat using CO_2 sequestering technologies.

iii. Build centralised co-generation and large energy use 'complexes'.

iv. Use biotech to produce most food in or near the city rather than using energy-intensive freight systems from southern countries.

v. Rationalise the goods delivery (freight) system of the city. It is currently a major consumer of energy.

vi. Develop an inner city transit system focused on public transit, taxis, walking and biking rather than private vehicles.

vii. Develop a suburban land use and transit system focused on in-fill, public transit, taxis, walking and regulated, small, personal, zero emission vehicles.

viii. Create a high speed and volume urban information infrastructure to reduce traffic requirements.

ix. New and renovated buildings to use new technologies to become GHG central and zero-net-users of energy:
x. Light pipes
xi. P/V materials
xii. Sensors and controls
xiii. Temperature gradient heating and cooling
xiv. Compact urban form

xv. High speed, low energy use trains to replace plane travel in the urban corridors.

xvi. Reclaiming existing multi-lane roads for a mix of:
xvii. Rapid transit and intelligent vehicles
xviii. Open space greenery
xix. Building infill
xx. Walking and biking

xxi. Re-arranging urban land use to serve older populations. Bring residences, jobs and caregiver services within easy walking distance in 'nodal' communities.

CONCLUSION

The above ideas begin to indicate the potential role of the municipality in shaping energy systems and use in the 2030-50 period. An essential issue is whether the municipality could be a leader in applying GHG reducing technologies. For the moment, there are few indications that municipal politics or planning is focused in any way beyond a five-year horizon.

ATTENDEES:

Richard Gilbert, Consultant Centre for Sustainable Transportation
Danny Harvey, Professor University of Toronto Geography
Juri Pill, A/President of Toronto District Heating Corporation
John Warren, City of Toronto
Bob Bach, Dukes Solutions
Bob Dawson, City of Toronto
Laura Van Zittwitz, Urban Planning, City of Toronto
Kevin Cliffe, Director for ETF
Lindsey Patrick, Economic Advisor for ETF
Glen Milne, Consultant

SUMMARY REPORT OF THE ETF
RENEWABLE ENERGY FOCUS GROUP
February 18, 1999
National Research Council
Ottawa, Ontario

PURPOSE

The purpose of the focus group was to:

- Develop views on the potential role of renewable energy technology in Canada's energy system in 2050.
- Identify the renewable technologies that Canadians could be using during this period.
- Identify the particular niches could they address.
- Identify the R&D priorities, technical gaps, and critical technologies for the area.

RENEWABLE ENERGY IN THE 2030 – 2050 ERA

The focus group thought that renewable energy would continue to expand its role in the future. Renewables were seen along with increased energy efficiency and decarbonization of fuel as having significant roles to play in green house gas mitigation.

The focus group assessed the viability of different technologies over a map of Canada. It took into account geographical distinctions as well as rural/urban and on-grid/off-grid circumstances. The result was a mix of different renewable technologies in different niche areas. Off-grid solar and wind in northern Canada, wind power on the coasts, and an on-grid mix of renewables in the south with shared inter-provincial power and storage across the country. The map showed that there were definite niches within Canada for certain technologies and a probability 'thickness' for renewable technologies could be developed to assess their potential.

The group also outlined various technological paths for the coming century. Milestones were placed in certain times and sectors to indicate what could be met with different technologies. While the group noted a steady rise in the rate of renewable energy use (with its market share doubling over the next 50 years), breakthroughs in nuclear energy, energy storage, and sustainable hydrocarbon technology may change how much renewable energy we could use in the future.

ENABLING TECHNOLOGIES

The focus group also identified many critical technologies needed to make renewable energy more efficient, versatile, and viable. Low cost, high density energy storage was identified as being important to all aspects of the energy infrastructure, although, it was noted that efficient storage may take away some of the niche areas of renewables.

Better inverters, converting DC power to AC power and vice versa, were also identified as being very useful for wind and hydroelectric power. Combing better inverters with low speed generators will make small hydroelectric and low speed wind turbines more efficient.

The focus group also viewed hybrid renewable/hydrocarbon power plants and transport systems as being a possible option. Renewable energy could provide small amounts of electricity or low-grade heat at different points of a hydrocarbon fuel burning process.

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Attachment

Renewable Energy Technology Cards

Active Solar

- Photovoltaic cells that use a very wide range of the electromagnetic spectrum
- Cell solar to electricity conversion rates of up to 70%
- Solar tracking by non-mechanical means
- Optical films that concentrate solar energy
- Polymeric based solar cells as opposed to solid state semiconductors
- Light weight, high durability cell materials

Solar Thermal

- Thermochromatic materials for water heating that change their optical properties with temperature, i.e. heater changes colour from black to white at 100° C
- Non-corrosive and non-freezing fluids for heat transfer
- Solar powered desalination plants

Passive Solar

- Phase change materials that change state at 22° C
- Wallboards and floors that change their crystalline structure with the addition of heat
- Low cost, changeable window glazing

Wind Power

- Micro-friction bearings for moving parts
- Low RPM generators to eliminate gearbox assemblies in turbines
- No moving part turbine that uses ionised particles between two charged plates, the wind's kinetic force pushes the resistive ions into the positive plate and creates a current
- Wind blade materials that can shed ice

Biomass

- Hydrogen generation through anaerobic digestion of biomass
- Use of bark in other hard to process biomass in fuel production
- Genetically engineered biomass that produces more ethanol

Geothermal and Hydrothermal

- Advanced heat retention fluids that absorb and release heat readily

Hydroelectric

- Creating small hydro structures from coral or other biological means
- Penstock drilling and piping by small remote robots for easier and more versatile construction
- Low speed generators for low head sites

Ocean Power

- Tidal power exploitation at the Bay of Fundy and other sites
- Ocean thermal gradient power from the southernmost Canadian sea areas
- Current power from oceans and rivers